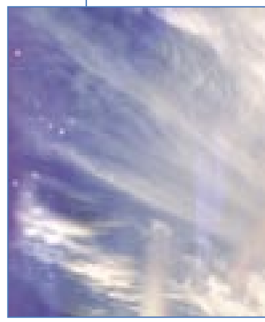


3 Resources

3.1 NASA Research and Space Flight Centers

NASA Research and Space Flight Centers maintain the core expertise to conceptualize, develop, deploy, and utilize systems for Earth observations from space. Center investigators serve as mission science team leaders and members, bringing critical scientific expertise with a research perspective to mission planning, operations, and data analysis. Their long-term commitments provide the intellectual continuity that is critical to successful satellite missions, spanning decades from conceptualization to final data products. Center scientists can dedicate their effort to specific observations or scientific problems and make long-term commitments to science teams prepared to undertake complex, interdisciplinary research tasks. With their focus on NASA research, centers become important repositories for the knowledge garnered from successful missions as well as for the lessons learned from less-successful efforts. This perspective is critical to both short-term and strategic research planning within the Agency.

Satellite missions and increasingly many other aspects of Earth science research rely on complicated technology developed within NASA centers and associated institutions, and NASA looks to its research programs to drive the development of critical technological resources. Day-to-day contact at NASA centers between research scientists and engineers facilitates creativity and innovation in technology while helping to insure research requirements are met. Similarly, constant exposure to technological developments provides center scientists strong understanding of emerging options, frequently fueling new ideas and research directions.

3.2 Extramural Investigators

A broad community of investigators working in universities, government laboratories, and other research institutions throughout the world bring to NASA's Earth science research the diverse talent, training, and experience demanded by the Agency's interdisciplinary Earth system science approach. University investigators undertake approximately half of NASA's research tasks in Earth science, ranging from highly focused studies by graduate students with principle investigator guidance to satellite missions led by university investigators. At a number of institutions, teams of investigators work together with support from multiple grants or cooperative agreements, forming critical cross-disciplinary expertise. These teams may focus on specific themes or questions for extended periods, developing centers of excellence within their institutions. University investigators and scientists working at government laboratories have important roles in working groups and committees that help set research priorities and guide programs.

NASA centers maintain close partnerships with a number of universities. In some instances, university faculty work for extended periods at NASA centers, taking advantage of unique center facilities and expertise while providing their personal research perspectives. Such partnerships offer excellent opportunities for student participation in NASA Earth science research.

3.3 High-Performance Computing

Effective use of Earth observations challenges the capabilities of the world's high-performance computing systems. Our ability to predict changes in the Earth's environment depends critically on simulating biogeochemical cycles, climate, weather, and natural hazards. Such Earth system simulations, based on accurate representation of a diverse set of interacting physical, chemical, and biological processes over time scales from days to centuries, constitutes one of, if not the, most demanding computational challenges facing scientists today.

The computational demands of Earth observing systems extend from the acquisition of data from platforms in space to comprehensive Earth system simulations. The volume of remote sensing data products makes their routine production, storage, and distribution major computational requirements with unprecedented network and storage demands. Global climate and atmospheric chemistry simulations illustrate the computational demands of Earth system analyses. When satellite observations are assimilated into these simulations, the combined computational demands of data handling and model solution constitute a grand challenge in computing.

With unique capabilities in both Earth science research and the development of advanced technology, NASA is poised for a leading role in addressing these challenges. NASA is deploying advanced research computing systems at several levels as well as research and development to derive, test, and implement the algorithms and other software systems required to make effective use of the emerging hardware architectures best suited to each research task.

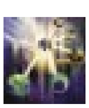
Through partnerships between NASA and industry, Project Columbia seeks to extend significantly the nation's high-performance computing capabilities. Capitalizing on proven technology to enhance capabilities not targeted by other leading systems, Project Columbia will develop National assets available to multiple U.S. agencies through a competitive selection process. The project will make computational resources, including networking between NASA centers, available to NASA investigators as they are developed.

Most recently, NASA acquired a cluster of 20 coupled 512 processor systems for a total of 10,240 processors. As part of Project Columbia, this high-performance system located at the NASA Ames Research Center will on completion increase NASA's high-performance computing capacity approximately 10 fold.

NASA is also investigating alternative computing architectures. Recognizing that there is no "one size fits all," the Agency is taking an overall look at what are the most reasonable architectures to satisfy computational requirements. For example, climate modeling and geodynamic modeling may require tightly coupled computing systems while earthquake modeling can tolerate loosely coupled clusters. In the future, multi-tiered computing center architecture will be built to satisfy different Earth science modeling requirements. The data system will be separated from the computing engines. A high-speed network will connect the computers with the data system and a data management system will keep track of all the data generated by the models. A wide area network connecting multiple NASA centers and universities will be used to transfer large volume of data between research groups distributed around the country.

New technologies such as Field Programmable Gate Array (FPGA) and Processor in Memory (PIM) have shown tremendous promise in on-board data procession and may be suitable for certain type of data assimilation and Earth system modeling. These will be closely watched and partnership with other agencies will be developed to exploit these alternative architectures.

Recognizing that advances in the science of Earth system modeling will require contributions from many scientists, it



is imperative that the models used be part of a Earth System Modeling Framework (ESMF) that allows for use of different model components interlinked in ways that allow for easy substitution and consistent use of data, while still maintaining high throughput and taking full advantage of the capability of the computers used. The development of this framework, which involves participants from most of the major modeling centers in the US, will enable the more rapid implementation of new algorithms into the research and assessment codes used for Earth Science modeling.

3.4 Data and Information Systems

With its focus on observations, NASA Earth science research depends on advanced data systems to acquire measurements, produce data products, provide active archives, and distribute data to research investigators. The Earth Science Data and Information Project provides scientific users, as well as a large and diverse general user community, with access to NASA's Earth science data, primarily through the Earth Observing System Data and Information System (EOSDIS). EOSDIS commands and controls NASA Earth Observing System satellites and manages data from satellites and field measurement programs, providing active archive, distribution, and information management.

Currently, NASA Earth observing satellites provide about 500 Gbytes/day (500×10^9 bytes/day) of instrument data from space, producing approximately 4 Tbytes/day (4×10^{12} bytes/day) of data products. Each year, NASA's space assets contribute about 1.4 Pbytes (1.4×10^{15} bytes/day) of data to Earth science research. This enormous data stream is the primary resource for and focus of Earth science research with NASA and fuels a broad range of research, application, management, and decision activities worldwide. As investigators better understand Earth observations from space, they improve data products and develop new ones, thus increasing data resources and at the same time data system requirements.

Currently managing more than 1,450 data sets and distributing data to more than 100,000 users, EOSDIS continues to serve as the primary active archive and distribution system for Earth observations obtained by NASA. Eight Distributed Active Archive Centers (DAACs), representing a wide range of Earth science disciplines, process, archive, and distribute NASA Earth observation data. Additional, tailored information products are generated and distributed by competitively-selected members of the Research, Education, and Applications Solutions Network (REASoN).

Many science data products are produced on Science Investigator-led Processing Systems under the direct control of instrument teams while others use the science data processing systems within the DAACs. In either case, the algorithms and quality assurance are provided by instrument teams.

NASA is committed to evolving its data systems to facilitate information synthesis and timely and affordable access to information and the knowledge it generates. The strategy for the next decade is to evolve data systems consistent with the science focus areas described in chapter 2 of this plan with integration across focus areas through predictive models. The major elements of the Enterprise strategy for data management are:

- Identify and generate validated climate data records in collaboration with the science community and our domestic and international partners.
- Create data assimilation capabilities sufficient to exploit the diverse data types (e.g., new satellite, sub-orbital, and in situ observations) available to create the data records needed to address Enterprise science questions.
- Participate in the development of computational, networking, and data storage/access resources to link models and assimilate observational data from diverse and distributed institutions into coupled and comprehensive Earth system models.
- Link research investigators, computational technologies, and industry to assure that evolutionary and revolutionary capabilities become available to meet rapidly-growing future performance requirements
- Lead the development of on-board computing capabilities (i.e., reconfigurable computing) to enable web sensor reconfiguration and optimization of communications bandwidth.

These will be further articulated in a new Data and Information Management Plan currently under development with NASA's external science advisory committee.